Long-Term Multifrequency Polarimetric Observations of the Sea Surface Emission

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LONG-TERM GOALS

The long-term goal of this research is to provide passive microwave observations in conjunction with *in-situ* ocean surface measurements in order to improve empirical and geophysical models of the effect of the ocean surface wind vector on microwave brightness temperatures. Improvements in these models are expected to increase the accuracy of ocean wind vector retrievals from microwave data collected by spaceborne polarimetric microwave radiometers. Airborne and spaceborne ocean sensors necessarily average over large areas (from hundreds of meters to tens of kilometers in diameter) of the surface. Therefore, these sensors measure the integrated emission from a wide variety of sea states or surface conditions. Near-surface observations from geographically dispersed platforms, accompanied by *in-situ* data, contribute additional quantitative knowledge of surface and sea state effects, providing information to improve ocean surface emission models.

OBJECTIVES

Accurate retrieval of the wind vector requires knowledge of the relationship between ocean surface properties and the directional component of the microwave emissivity. Models for the wind *speed* dependence of SSM/I brightness temperatures have been well validated through ground truth during the past 14 years. Radiometric measurements from aircraft circle flights have demonstrated wind *direction* signatures in all four Stokes parameters of the microwave emission from the ocean surface (e.g., [1-4]). However, uncertainties remain in the application of geophysical forward models to predict observed microwave brightness temperature variations based on the wind direction (e.g., [4-7]). Long-term passive polarimetric observations of the sea surface emission from a variety of ocean locations are needed for reliable determination of the dependence upon sea state, surface properties, air-sea instability, and other parameters.

The principal objectives of this three-year program are twofold. The first objective is the design, development and fabrication of a K-band (18.7 GHz) polarimetric radiometer at the University of Massachusetts (UMass) Amherst. The second objective is to perform platform and pier-based measurements of the four Stokes parameters of microwave emission from the ocean surface to observe their dependence on air-sea instability, wind speed and direction, foam and swell. These measurements are to be performed using two polarimetric radiometers: the new K-band and an existing Ka-band (36.5 GHz).

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14. ABSTRACT
The long-term goal of this research is to provide passive microwave observations in conjunction with in-situ ocean surface measurements in order to improve empirical and geophysical models of the effect of the ocean surface wind vector on microwave brightness temperatures. Improvements in these models are expected to increase the accuracy of ocean wind vector retrievals from microwave data collected by spaceborne polarimetric microwave radiometers. Airborne and spaceborne ocean sensors necessarily average over large areas (from hundreds of meters to tens of kilometers in diameter) of the surface. Therefore, these sensors measure the integrated emission from a wide variety of sea states or surface conditions. Near-surface observations from geographically dispersed platforms, accompanied by in-situ data, contribute additional quantitative knowledge of surface and sea state effects, providing information to improve ocean surface emission models.

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APPROACH

Toward the first objective, the design of the new K-band polarimetric radiometer is principally based on that of the Ka-band polarimetric radiometer, which was rebuilt at UMass during 2000 under a synergistically related program, also funded by the ONR Remote Sensing and Space Division. Both polarimetric radiometers are based on a Dicke design for the total power channels to obtain the first two Stokes parameters, T_v and T_h. A polarization-correlating radiometer design is used to obtain the third and fourth Stokes parameters, *U* and *V* [8]. Each of these radiometers is thermally insulated and controlled to maintain a constant operating temperature. Any gain variations between external calibrations are compensated through Dicke-mode measurement of an internal noise source for the "hot" calibration.

A new internal polarimetric calibration technique is implemented in both the Ka-band and K-band radiometers [9]. Additional RF switches allow the noise source signal to be input to both channels simultaneously, and a digitally controlled phase shifter alters one channel's path to provide a calibration circle. The radiometers each contain an embedded Pentium-II computer, data acquisition and FPGA-based digital controller, all in the PC-104 architecture. External control and near real-time data viewing are achieved through a single network interface, so that Ethernet and power cables are the only external connections to the radiometers. In the Ka-band radiometer, a ferrite polarization rotation device is located in the throat of the antenna and is periodically switched from 0˚ to 45˚ rotation in order to obtain T_p and T_m instead of T_v and T_h. This design is one implementation of polarization-combining to obtain the third Stokes parameter U, equal to the difference between T_p and T_m (e.g., [5]).

The first set of measurements toward the second objective using the Ka-band polarimetric radiometer was carried out aboard the R/P FLIP in the Pacific Ocean during September and October 2000, as part of the Fluxes, Air-Sea Interaction and Remote Sensing experiment. An X-band polarimetric radiometer was deployed by Drs. L. A. Rose, P. W. Gaiser and K. M. St. Germain of the Naval Research Laboratory (NRL) in Washington, DC. In addition, Dr. W. Asher of the University of Washington Applied Physics Laboratory recorded video data to perform foam coverage measurements. The UMass effort was sponsored by ONR Remote Sensing and Space (Award #N00014-00-1-0280). Results from that field experiment are described in a separate grant report.

The second set of near-surface radiometer measurements was performed during December 2000 and January 2001 as part of the international Wind and Salinity Experiment (WISE 2000), co-sponsored by the European Space Agency, with the participation of six institutions from Spain, France, and the U.S. Fully polarimetric L- and Ka-band radiometers and video, IR, and stereo cameras were installed on the *Casablanca* oil platform in the Mediterranean Sea, ~40 km offshore from Tarragona, Spain. The L-band radiometer observations assessed the effects of wind speed, direction, sea state, and sea surface temperature on forward models for changes in brightness temperature due to salinity variations. Nearby oceanographic and meteorological buoys provided *in-situ* sea surface temperature and salinity, significant wave height, wind speed and direction, as well as other meteorological parameters. Sea surface skin temperature was obtained from the infrared camera measurements. The stereo optical cameras documented foam coverage and estimated sea surface spectra during the experiment.

Figure 1. The UMass Ka-band polarimetric radiometer (left) on the Casablanca oil platform (right) in the Mediterranean Sea during the Wind and Salinity Experiment 2000.

The third set of measurements was performed as part of the Rough Evaporation Duct (RED) Experiment sponsored by ONR's Processes and Prediction Division, Marine Meteorology. The RED experiment focused on assessment of the effects of the air-sea boundary layer on microwave and electro-optical propagation. As part of RED, the new K-band polarimetric radiometer was deployed from the face boom of FLIP to measure the sea surface during September 2001 (see Figure 2). Coordinated *in-situ* measurements performed by other researchers during RED include wind velocity, temperature, humidity, and pressure at six heights near the sea surface (C. Friehe, UCI); upper ocean bubble size distributions (E. Terrill, SIO); sonic anemometer data on atmospheric turbulence and dissipation flux (K. Davidson, NPS); and aerosol measurements from a variety of sensors and groups.

Figure 2. The UMass K-band polarimetric radiometer measured the sea surface from th e face boom of the R/P FLIP during the RED experiment in September 2001.

WORK COMPLETED

The first objective was met with the completion of the design and fabrication of the new K-band polarimetric radiometer (see Figure 2) in August 2001. This new passive microwave instrument was successfully deployed during the RED experiment in Hawaii.

Toward the second objective, the WISE 2000 experiment was completed in January 2001, during which Ka-band (36.5 GHz) passive polarimetric measurements were performed for 22 days from an oil platform in the Mediterranean Sea. Forty scans over a range of 100˚ in azimuth were completed at each of 35˚, 45˚, 55˚, and 65˚ incidence angles. Each angle was viewed for four minutes, two minutes in each of the two polarization rotation states, each lasting about 20 ocean gravity wave periods. The radiometer's gain and offset were found using two characterized external microwave sources. A "cold" external source for radiometric calibration was the microwave emission of the atmosphere measured at a series of zenith angles. An ambient microwave absorber was the "hot" source for external calibration of the radiometer.

The RED experiment was completed in September 2001, during which the K-band (18.7 GHz) passive polarimetric radiometer observed the sea surface for 14 days from the R/P FLIP moored 9 km off Oahu, Hawaii (see Figure 2). More than 40 scans were performed over a range of 220˚ in azimuth, at each of 35˚, 45˚ and 55˚ incidence angles.

RESULTS

The results of Ka-band measurements in the Mediterranean Sea are discussed in this report. The K-band measurements near Oahu, Hawaii, will be analyzed during FY02.

Preliminary results from the WISE 2000 experiment include time-series data demonstrating the expected effects of modulation of the local incidence due to gravity waves (see Figure 3). Second, azimuthally-averaged vertical and horizontal brightness temperatures compare favorably with predicted values at wind speeds from calm to >10 m/s (see Figure 4). The solid curves in Figure 4 show simulation results from a geometric optics model described in Camps and Reising [2001], ignoring multiple reflections and shadowing [7]. Further analysis of the extensive WISE 2000 and RED 2001 measurement sets is ongoing.

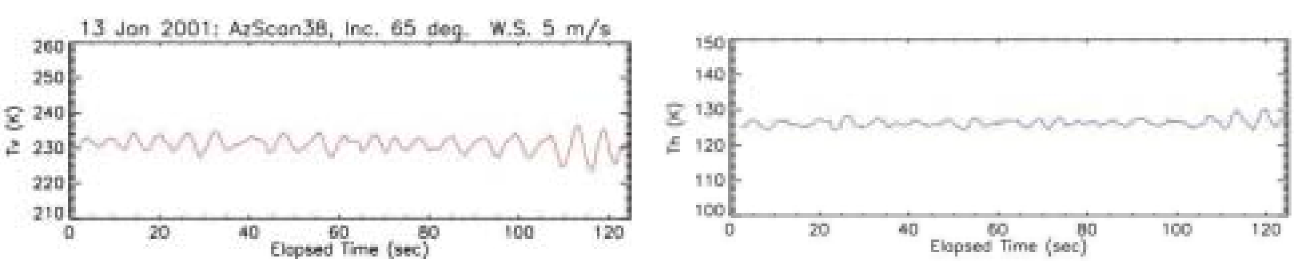

Figure 3. Time series measurements of the vertical (left) and horizontal (right) brightness temperatures of the ocean surface during WISE 2000. The wind speed is 5 m/s.

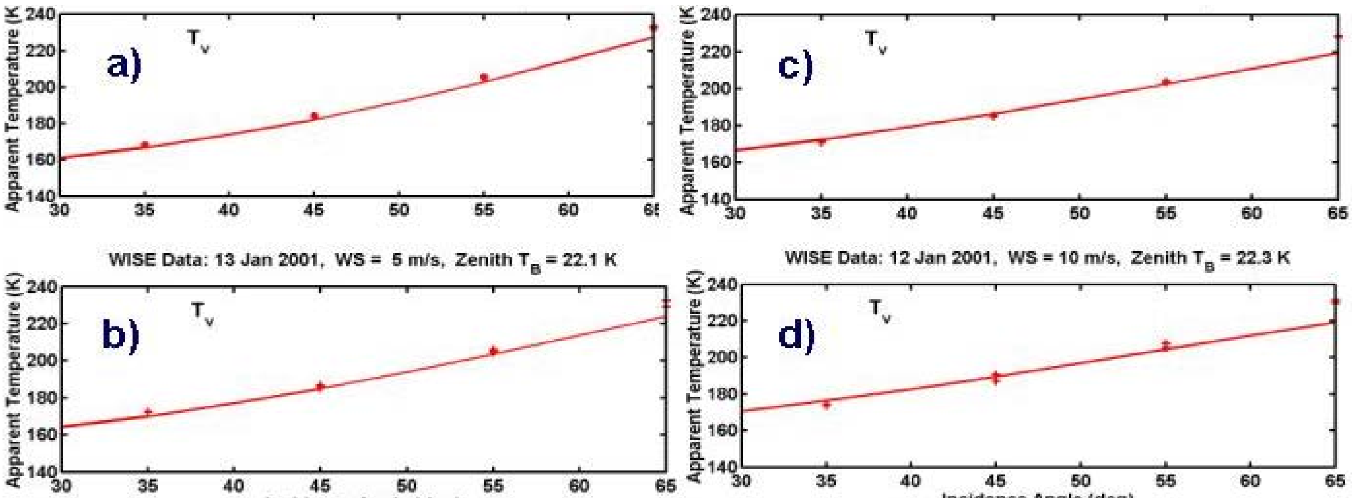

Figure 4. Azimuthally-averaged vertical brightness temperatures vs. incidence angle for different wind speeds, a) WS = 2 m/s, b) WS = 5 m/s, c) WS = 8 m/s, and d) WS = 10 m/s. Solid lines show simulation results found using a GO model.

IMPACT

The results of long-term passive polarimetric observations of the sea surface, along with coordinated *in-situ* measurements of wave, atmospheric, and sea surface properties, are expected to provide comparison data to validate and improve geophysical models of sea surface emission. One set of geophysical forward models, under development by R. Bevilacqua and colleagues at NRL in Washington, DC, is planned for use in the operational retrieval of the ocean wind vector from passive polarimetric spaceborne measurements from WindSat, after its planned launch in 2002.

RELATED PROJECTS

A related ONR grant, “Passive polarimetric measurements of the effects of foam and roughness on microwave emissivity,” along with collaborative work by NRL and Univ. of Washington researchers, has produced quantitative results on the effects of foam on sea surface emissivity. The X-band and Ka-band radiometric measurements performed from the R/P FLIP during FAIRS are expected to provide a unique and useful dataset for the present program.

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